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NECTURUS

A LABORATORY MANUAL

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NECTURUS

A Laboratory Manual

BY

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PREFACE

This manual has grown out of a number of years' use of Necturus in large classes. It was felt that a manual was needed to settle the questions usually asked about the work by the student.

Necturus is desirable for dissection because of its distribution and availability. Its size recommends it as a laboratory specimen and its more or less simple organization makes it a good form to be used after the usual work on the shark or other fish.

Although extensive work has been done on Necturus, much remains to be discovered by future research. Some material appears here for the first time and some corrections in procedure have been made. Full advantage has been taken of all that has been done in the past and acknowledgments must be made to Mivart's "Notes on the Myology of Menobranchus lateralis," *Proceedings of the Zoological Society of London*, 1869; to Kingsley's "Necturus, an Urodele Amphibian"; H. H. Wilder's "The Skeletal System of Necturus maculatus, Rafinesque." *Memoirs of the Boston Society of Natural History*, Volume V, 1895. W. S. Miller's "Contributions from the Anatomical Laboratory of the University of Wisconsin," No. 33, 1900. Other assistance has been gathered from special books and papers that have dealt wholly or in part with this form.

The nomenclature used is mixed in its origin and is chosen for its clearness and simplicity.

In general the terms used are those of the more modern

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papers and textbooks. The writer will appreciate reports of errors that undoubtedly exist in the manual.

I wish to express my appreciation of the work of Dr. F. B. Adamstone in looking over the proof and making valuable suggestions.

L. A. ADAMS.

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NECTURUS

A LABORATORY MANUAL

THE NECTURUS

INTRODUCTION

This member of the amphibian group is a very desirable form for dissection, since it represents a rather simple tetrapod. It is a curious mixture of specialization and primitiveness with the latter predominant. The lungs may have been better developed at one time than they are at present, but now they are very small, inefficient and unable to carry on the work of respiration without the aid of gills.

A number of the amphibia have been left in the halfway position of being neither water nor land animals, and these possess both lungs and gills throughout life. Due to the possession of a moist glandular skin, the amphibia have never been able to separate themselves from water to the degree possible in forms with a dry skin. In order to secure the fertilization of their eggs most amphibians have to go to water to deposit them, although a few have developed so far into land animals, that the metamorphosis takes place in a very short time after hatching, thus enabling them to lay their eggs in damp places. A few have developed so that they are able to bring forth their young alive. All others must make an annual pilgrimage to water for egg laying. A small number have lost both gills and lungs and must depend on other parts of their bodies for the purification of their blood. Pharyngeal passages, richly supplied with blood vessels, help in the aeration in the lungless forms.

The main justification for describing Necturus as primitive lies in some similarities between its structure and that of the fish. The body outline is fishlike, with myocommata showing as zigzag lines separating the myotomes. The head musculature is simple and unspecialized while the limb musculature is more complicated, as would be expected in an animal with the tetrapod type of limb. This suggests some very interesting history back of the limb musculature that has never been discovered. The skull is quite specialized, having lost several bones including the maxillae. The feet have lost one toe.

The circulation shows the influence of lungs and air breathing. As in all amphibia, the heart is three chambered, but other parts of the circulating system remain a mixture, containing characteristics both of water and air type.

The arterial arches are reduced from the primitive number six to three. The sixth becomes the pulmonary artery, the fourth becomes the systemic, and the third with parts of the anterior arches become the vessels of the neck and head. The posterior cardinals lose their importance and become small, their place being taken by the new postcaval. The iliacs acquire a new connection with the renal portals, while the lateral veins join and connect with the hepatic portal, thus making several paths for the outlet of the blood from the hind limbs.

CLASSIFICATION OF THE AMPHIBIA

For the convenience in placing Necturus in its position in the animal kingdom, this classification is given.

Phylum Chordata
Subphylum Vertebrata.
Superclass Tetrapoda
Class Amphibia

Subclass Stegocephalia
Subclass Batrachia
Order Gymnophiona
Order Urodela (Caudata)
Order Anura.

Necturus belongs to the Urodela or tailed amphibians. The suborder Proteida to which it belongs retains the gills permanently. The characters of the family Proteidæ are the same as those of the suborder. This genus has two species in the United States, maculosus found in the Mississippi Valley and east to the Atlantic and punctatus found only in the southeast.

HABITS*

Much remains to be learned of the habits of this form. It is found in the rivers and lakes where conditions are suitable over the northeastern region of the United States, with a smaller species punctatus, in the southeastern portion.

The food consists of crayfish, insect larvæ and nymphs, small crustacea, mollusca, an occasional minnow, plant remains and rarely fish eggs. They take a worm readily and are often caught on a hook with this bait.

In the late fall and winter the cloacal region of both sexes are swollen. At this time they are together in the shallow waters along the shores where they can be seen at night in the light of the "jack," either moving slowly about among the rocks or lying motionless. During the winter they are occasionally seen through the ice, so it is certain that they are active all winter.

The eggs are laid in the spring, probably about April. It is believed that the females are impregnated by the

* This information was supplied by Dr. A. R. Cahn of the University of Illinois Department of Zoology.

males in the fall and that the females carry the sperm all winter. In fact males examined in winter yielded no spermatozoa when stripped nor the testes yield milt when cut. It is not certain as to whether copulation takes place or whether the female takes in the spermatophores of the male.

The eggs are laid under the sides of flat stones or under immersed pieces of wood. They are deposited singly, being attached to the overhanging support by the outer jelly like membrane. The number of eggs in a clutch varies from 25 to 90 with an average of about 75.

Many nests or clutches may be found under the same board or rock, each guarded by the female. The male is never evident around the breeding ground after the eggs are laid. The eggs hatch about the last of June, the nearly white young falling to the bottom where they remain for several weeks, feeding on their stored yolk. Larvæ a year old are about two and a half inches long. They are curiously marked with stripes at this age. The age at which they breed is unknown.

EXTERNAL FEATURES OF NECTURUS

Study the living animal, where it is possible to have a specimen in the laboratory. If material is available, it is very valuable to compare this Urodele with the representatives of the other classes of vertebrates.

DRAWING 1. Make a drawing of a dorsal view showing the position of the limbs and their relation to the body. What is the general shape and plan of the body?

Locate all of the openings of the body and list their position. Is there a neck? What is the general shape of the head? What is the shape and position of the mouth? Are lips present? Note the position, shape and size of the nose. Probe with a bristle and find the connection with the mouth. What is the position, size and covering of the eye? Is there an external auditory meatus. What forms the gular fold? Why does this exist? Study the gills and find the number, position, and character. Explore the openings into pharynx. What are the transverse lines extending from the mid-dorsal to the mid-ventral line? How many of these are there between the anterior and posterior limbs. Is the tail typical of a terrestrial or an aquatic animal? What is the number of the appendages? Are they of the tetrapod type? What is their position? Compare them with the fins of the shark. Are the feet webbed? How many toes are there on the limbs? Is the type of leg that of the swimming animal? What is the distribution of the color? Is it the usual color distribution found in water animals?

SKELETON

The skeleton of a primitive type in most of its particulars. It represents the early adaptations of the tetrapod to land life, combined with many characters that are related to water living.

For convenience the skeleton is divided into three divisions; the axial consisting of the skull, vertebral column, ribs and sternum; the appendicular, consisting of the limbs and their girdles; and the visceral consisting of the supports of the gills and the parts deprived from them.

Axial Skeleton

Note the divisions of the axial skeleton and the position of the limbs in relation to the vertebral column. The ribs extend to the head with the exception of the first cervical where they have been lost.

SKULL

The flat platybasic skull contains a reduced number of bones, some having been lost. There is also a part that remains cartilage. This may be studied by boiling the skull gently and manipulating with a needle. This should be done after the bones of the skull have been studied.

Drawing 2. Make a drawing of the dorsal surface X 10.

Dorsally the median series consists of the **premaxillæ,** at the anterior end followed by the **frontals** and **parietals.** All of these bones are paired. The **exoccipitals** each supply one of the two condyles present in the amphibia. The **supraoccipital** is not ossified. From the dorsal side, the

paired **vomers** seen extending posteriorly and laterally from the **premaxillæ**. They are ventral bones but appear on the side of the skull. A part of the **trabeculæ** is retained as cartilage along the side of the skull and may be seen at the side of the anterior extensions of the **parietals.** A large **preorbital cartilage** extends out between the **vomer** and the **palatoquadrate.** The **palatoquadrate cartilage** extends out laterally from the ossified **quadrate.**

The **quadrate** marks the articulation of the jaw with the skull and supplies a landmark for the identification of some of the bones. Posterior to the **quadrate cartilage** is an ossification of the **chondrocranium,** the **prootic,** which is partially covered by the **parietal.**

The **opisthotic** forms the postero-lateral angle of the skull. It is ventral to the **parietal** and the **squamosal.**

Drawing 3. Make a drawing of the ventral side of the skull X 10.

The **premaxillæ** are the anterior elements with teeth. The maxillæ are entirely missing. A cartilaginous area separates the **vomers.** The under part of the skull is formed mostly by the large median **parasphenoid.** The **palato-pterygoids** appear on the ventral side, extending laterally and posteriorly. A small articulating portion of the quadrate appears as the condyle. The squamosal is a thin plate of bone that connects the quadrate and the opisthotic. The prootic appears in the region between the parasphenoid and the outer line of the skull. The circular **stapes** with the columella fits over the fenestra vestibuli which is in the cartilaginous capsule of the ear.

By using a razor blade that has been nicked slightly, the skull may be sawed in two to show the size of the brain case, the organization of the inner part, and the relation of the brain to the brain case.

Teeth are found on the premaxillæ, vomers, palatines and palato-pterygoids.

BONES OF THE SKULL

By boiling the skull of the specimen used for dissection a very good disarticulated skull can be obtained. Boil for half an hour in a mixture of soap, ammonia and borax. Separate the bones, one at a time so as to be sure of the relations. It is better to use the left side for the disarticulation thus keeping the right side intact for comparison. It will be necessary to use a safety razor to split the parasphenoid.

The following bones do not appear in the skull of Necturus; maxilla, occipitals, the maxilla is lost entirely, the occipitals are not ossified, and the palatines have joined with the pterygoids to form the palato-pterygoids.

Premaxilla

The **premaxilla** is a V shaped bone at the anterior end of the skull. Its inner limb rests on the frontal, which is its only articulation with the other bones. The exterior limb of the V is free and extends posteriorly along the vomer. The underside of the free limb is supplied with a number of conical teeth.

Vomer

The **vomer** is a flat, triangular bone forming a part of the upper jaw. The outer region of the ventral face bears a ridge upon which are numerous fine teeth. Most of the teeth of the upper jaw region are on this bone. There is an articulation between the vomers. Besides this they articulate with the **parasphenoid**, and **palatoquadrate**. The dorsal side of the bone bears an elevated ridge that extends dorsally and articulates with the frontal.

Palato-pterygoid

This combined bone is long, thin and somewhat rectangular in shape. It connects the **vomers** and the

quadrate. The anterior, outer surface bears a number of teeth and completes the dentition of the upper jaw at the posterior end. The anterior, inner surface articulates with the vomer. The posterior end of the dorsal face has the articulating surface for the quadrate. This articulation is of the flat contact type. There is a small articulating surface at the posterior inner edge for the prootic and a small attachment on the outer edge with the quadrate cartilage. The bone forms the anterior brace for the quadrate.

Quadrate

The quadrate is firmly joined to the ventral side of the squamosal by a long, flat surface articulation. These bones can be separated with a little care in softened specimens. The quadrate is an awl shaped bone, large at the anterior end where the articulating surface is situated and thin and pointed at the posterior end. A concave surface, well covered with cartilage supplies the articulation with the **articulare.**

The dorsal surface has a narrow, articulating face for the **squamosal.** Anteriorly it articulates with the **palato-pterygoid.**

Squamosal

This is a long, thin, curved plate of bone that is very regular in shape, with the exception of the knob on the inner ventral surface for the articulation of the **stapes.** The ventral side of the bone bears a long, flat, contact with the quadrate, to which it is very firmly attached. The anterior end is in contact with the **palato-quadrate** and the posterior with the **opisthotic.** It forms the posterior brace for the quadrate by uniting it to the posterior end of the skull.

Stapes and Columella

This combination of elements fits in the **fenestra vestibuli** of the inner ear. The opercular part is a flat concave disc where it rests on the fenestra. The outer surface bears the **columella** which extends dorsally and laterally, joining the articulating projection already mentioned on the ventral side of the squamosal.

Prootic

This is an irregular, cubical bone found between the squamosal and the brain case. The inner surface forms one of the walls of the inner ear. On the ventral side there is a large canal, the **mastoid foramen**. Dorsally there is a canal for the **anterior semicircular canal**. This canal opens out by a large foramen on the center of the posterior face. Use bristles as probes to determine the course of the canals. The **prootic** articulates with the **quadrate, palatopterygoid** and **squamosal** on its outer face, and with the **parasphenoid** and **parietal** on its inner.

Opisthotic

The **opisthotic** is located at the posterior angle of the skull. It is somewhat triangular in outline viewed from its dorsal surface, and oval from the anterior face. It forms the posterior wall for the inner ear and contains two of its canals. The **horizontal** canal enters its outer edge and opens into the inner ear by a large depressed opening in the center of the anterior face. On the ventral edge of the inner face, the **posterior canal** enters the bone. Follow these canals with bristles and find their course. It articulates on the outer face with the **squamosal**, on the inner with the **parietal**, on the central with the **exoccipital** and on the ventral with the **parasphenoid**.

Exoccipital

The **exoccipitals** border the foramen on all but the dorsal edge. This bone is anvil shaped in posterior view. The lower part of the posterior face is swollen to form the **lateral condyles** and the articulation with the **atlas.** The dorsal part widens out to articulate with the **parietal.** The inner edge bears a pointed projection which articulates with the **parasphenoid.** The outer edge articulates with the **opisthotic.**

Frontal

This is a long bone, thin at the posterior end where it makes a flat contact with the **parietal,** and irregular at the anterior end. The outer, anterior edge is drawn out into a process that articulates with the **vomer.** The ventral surface has an elevated ridge or **uncinate process** that articulates with the **parasphenoid** and helps in this way to form the anterior, lateral wall of the brain case. The two **frontals,** articulate with each other by a long articulation that is about two thirds the length of the bone. The posterior ends are separated by the **parietals** which form a wedge between them. At the anterior end of the dorsal face, the **maxillæ** lie on the frontals and articulate by a flat, contact articulation.

Parietals

The **parietals** are long, flat bones irregular in shape and forming the dorsal part of the brain case. The dorsal face has a roughened surface that forms the articulation with the frontals. The anterior end divides into two parts, a short part between the frontals and a larger one that extends laterally over the vomer and the anterior part of the chondrocranium. The dorsal face is comparatively smooth. There is a long articulation between the two

frontals along the inner edge. Posteriorly it articulates with the **exoccipital**, laterally with the **opisthotic** and **prootic**. The ventral face is marked by a distinct ridge that extends along the outer edge. This ridge forms the posterior wall of the braincase and articulates with the **parasphenoid**. This wall takes the place of the **orbitosphenoid**.

Parasphenoid

The **parasphenoid** is a flat plate of bone that forms the roof of the mouth and the ventral wall of the braincase. The ventral surface is flat while the dorsal surface has a pair of ridges that articulate with the **frontals** and **parietals**. The bone is wide at the posterior end and narrow at the anterior. The ventral face articulates with the vomers at the exterior end by a flat, contact articulation. Dorsally the bone articulates with the frontals by the ridge already mentioned, with the prootic and with the exoccipitals at the posterior end. There is no indication of the usual depression for the **hypophysis**, the pit usually known as the **sella turcica** of the higher vertebrates. This bone forms a large, single, median plate with no separation on the median line.

Mandible

The **mandible** of Necturus consists of three bones, the **dentary**, **splenial** and **angular**. The **articular** is cartilage.

The **dentary** is a large element, forming most of the jaw. There is a **symphysis** at the anterior end of the pair which is fairly firm. The upper edge bears a number of sharp, peglike teeth. Practically the whole of the outer surface of the jaw is formed by this bone.

The **angular** is on the inner side of the jaw and forms the posterior part of the inner surface. It sends a long, thin projection anteriorly along the **dentary**. It enlarges

at the posterior end to cover this part of the inner surface of the jaw. It bears no teeth.

The **splenial** is a small piece of bone applied to the inner surface, on the middle of the upper edge. It is not in line with the upper edge of the **dentary** so the teeth that it bears are not in line with the rest of the jaw.

The **articular** is a large unossified cartilage that supplies the articulation with the quadrate. The **Meckelian cartilage** is unossified and may be seen on the inner face between the **dentary** and the **angular.**

Braincase

The braincase is formed of cartilage and membrane bones. The following bones enter into its structure; **parasphenoid, frontal, parietal, prootic, opisthotic,** and **exoccipitals.** These along with cartilaginous material complete the braincase.

Drawing 4. Numbering posteriorly from the head, draw the second, twelfth and twenty-fifth vertebrae to show the differences in the vertebrae of the several regions.

Are there structural differences between the sacral and other vertebrae? Where do the first **hæmal processes** appear in the caudal vertebrae? The first cervical is modified from the rest of the series. The **centrum** is short and dorso-ventrally flattened with the anterior face modified to articulate with the **paired condyles** of the skull. Note the posterior end of the **centrum.** Is it hollow at this end? Is there any indication of a **notochord?** Is there a **prezygapophysis** or **postzygapophysis** on this vertebra? What is the shape of its neural canal? Is there an odontoid process? The atlas may have joined the skull, thus making the first cervical, the **axis.** An **odontoid process** on the first cervical would indicate this.

VERTEBRA

Twelfth Vertebra

Make a sagittal section through this vertebra.

Drawing 5. Make a drawing of the section showing the hourglass shape of the centrum and the relation of the centrum to the other structures of the vertebra.

Note the following parts: **prezygapophysis postzygapophysis, neural arch, neural spine, transverse process, parapophysis** and **diapophysis.** Is the vertebra **procoelus, amphicoelus** or **opisthocoelus?** Note the short rib attached to the **transverse process** by the two heads. On what vertebræ are the ribs found? Number them.

Twenty Fifth Vertebra (Caudal)

Note the shape of this vertebra in longisection.

Drawing 6. Make a drawing from the anterior face.

Note the development of the **hæmal arch** and **spine.** On what vertebræ numbering from the head posteriorly, are **hæmal arches** found? Why do these arches not appear earlier in the series?

Sacral Vertebra

Is there any structural differences between this vertebra and the rest of the series?

RIBS

The ribs in the amphibia are short and not connected with any ventral structures. Note the two heads of the rib, a *tubercular* and a *capitular.* With what processes do they articulate? On what vertebræ by number, are ribs found?

Appendicular Skeleton

Pectoral Girdle

Remove one of the legs and work out the girdle and the leg or better, have prepared specimens in alcohol for study.

The pectoral arch is mostly cartilage with the scapula the only ossified element. The procoracoid extends anteriorly, almost to the skull. The **coracoid** is the large posterior part of the girdle in which the **glenoid cavity** is found. The line between the **coracoid** and the **procoracoid** is not well marked. The **scapula** is the ossified dorsal element, which is capped by the **suprascapula**, a cartilaginous structure along the dorsal border. The girdles of the two sides are not articulated but overlap in the peculiar way, characteristic of the amphibia.

Pelvic Girdle

The **pelvic arch** consists of an arrow shaped structure composed of cartilage, but with some ossification in the **ischium** and **ilium**. The **ilium** extends dorsally and is connected with the sacral vertebra. This articulation varies considerably as it has been found on at least four different vertebræ, namely with the 18th, 19th, 20th and 21st. The attachment sometimes varies on opposite sides of the vertebral column for example the **ilium** of one side may be attached to the 18th vertebra while its fellow of the opposite side articulates with the 19th.

Anterior Limb

This is best studied in cleared specimens, but can be worked out from the formaldehyde material used in the class. The anterior limb consists of **humerus**, **radius**, **ulna**, **carpals**, **metacarpals**, and **phalanges**. It will be noted that

much cartilage remains in the limbs, especially at the ends of the bones.

The humerus is a straight bone with a **crista** on the ventral side for the insertion of muscles. These **cristæ** often mark such insertions. The radius and ulna are not much differentiated and do not resemble the bones of the higher **tetrapods**. They have undergone little specialization and are rather crude in their structure. The **ulna** is marked by an **olecranon process.**

The **hand** has but four digits, the first having been lost. The **carpalia** consists of six or seven bones; an **ulnare, intermedium** and **radiale** comprise the proximal series; the median series consists of a single or double **centrale**; while the distal series is made up of three bones, one of which probably represents two fused elements.

The fingers are considered to be *2-3-4-5 and the phalangeal formula **3-3-4-3. Do the fingers have nails?

The **femur** has large cartilaginous ends with a **trochanter** on the proximal. Is there much difference between the *tibia* and the *fibula?* The **tarsalia** consists of six or seven bones also; the proximal series made up of **tibiales** and the joined **intermedium** and **fibilare**; the intermediate series of a single centrale; and the distal series of three **tarsalia.** The **tarsalia** for digits 4 and 5 are joined. The formula for the digits of the foot are *2-3-4-5 and the phalangeal formula is **3-3-4-3.

Visceral Skeleton

For the most part the **visceral skeleton** is composed of cartilage, although some of the **basibranchials** may be ossified. The median series consist of two **basibranchials,** the first and second. The **hyoid arch** consists of **hypohyals**

* Refers to the numbers of the digits.
** Numbers refer to the number of bones in the digits.

and **ceratohyals**. The first visceral arch consists of **ceratobranchials** and **epibranchial**. The **ceratobranchials** of the second arch are small and missing in the remaining elements.

The gills are supported by the first, second and third **epibranchials**. There are traces of the fourth and possibly the fifth **epibranchials**.

DRAWING 7. Make a drawing of the visceral skeleton from the ventral view.

MUSCULATURE

The muscles of Necturus are characteristic of those in the Urodeles, in that they show many fishlike adaptations. The body muscles are divided into **myotomes** which are separated by **myocommata**. In the higher vertebrates this primitive arrangement is lost or can be seen only in such instances as the **tendinous inscriptions** and in some of the back muscles. Muscles are used to move various parts of the body and therefore each muscle has a place of origin and insertion. Usually the origin is on a fixed element while the insertion is on a part to be moved. Sometimes both the origin and insertion are on movable parts but instances of this are rare in skeletal muscles. Muscles are usually inserted on bone or connective tissue but some instances are found where insertions are on other muscles.

Muscles usually work in pairs since muscle fibers can do nothing but contract. To return to its original position, a second muscle is required to keep the muscular balance. The names used in this guide are for the most part those that indicate the nature of the work that the muscle performs. Names used in human anatomy have been avoided since the homology of the muscles in the Urodeles is uncertain.

The muscles of the limbs are often fusiform since this type takes up less bulk for the amount of muscular tissue involved. Triangular muscles appear where there are narrow origins and broad insertions, such as is found in the **pectoralis** or in some of the muscles attached to flat bones like the **scapula**. Sheet muscles appear in the **diaphram** where a solid sheet of uniform thickness is needed.

Muscles are usually associated together in pairs or opposing groups. Some of the names that appear are **depressor - levator, tensor - flexor, pronator - supinator, adductor - abductor, sphincter - dilator.**

The division of muscles into **voluntary** and **involuntary** is a very necessary development since internal parts must function with little or no attention from the individual. Involuntary muscles are found in the intestines, heart, and in other places where such a type is desirable. **Involuntary muscles** are unstriated except in the heart. **Voluntary** or **striated muscles** are attached to movable parts that must make more rapid movements.

The muscle insertion may be of several types according to the mechanical needs. Broad muscular attachments are found in regions where this type is most effective mechanically. In parts where space is limited, or bulk would be undesirable the muscles end in tendons. In the wrists and ankles for example, long tendons connect muscles with their attachments, thus reducing the size and making the part more flexible.

Since the parts of the body wear out, many adaptations will be found in the muscular and skeletal systems for preventing friction. Where muscles rub together they are protected by membranes. Where they pull over bone, pulley like arrangements are developed. In advantageous spots **sesamoid** or **tendon bones** are developed, such as the **patella** of the knee. These greatly lessen the possibility of over wear. Good examples of tendon bones may be seen in the legs of chickens and turkeys.

For convenience in consulting, a list of the muscles of various regions is given at this point.

Muscles of the Head and Throat

Masseter
Temporalis

Mylohyoid
Digastric or Depressor mandibulae
Geniohyoid
Ceratohyoid externus
Ceratohyoid internus
Levators
Levator arcuum branchiarum
Constrictors arcuum
Depressor arcuum branchiarum

Muscles of the Shoulder Region

Latissimus dorsi
Dorsalis scapulae
Cucullaris
Omohyoid
Procoraco-humeralis
Supracoracoid
Pectoralis
Serratus magnus
Levator scapulae

Muscles of the Upper Arm

Triceps
Biceps
Coraco-brachialis
Scapulo-humeralis

Muscles of the Carpus

Extensor metacarpalis
Extensor radialis
Extensor ulnaris
Supinator
Palmaris superficialis
Flexor ulnaris
Flexor radialis
Ulnaricarpalis
Pronator

Muscles of the Pelvic Girdle

Puboischiotibialis
Puboischiofemoralis externus
Puboischiofemoralis internus
Pubotibialis

Femoro-fibularis
Pyriformis
Ischiocaudalis
Femorocaudalis

Muscles of the Thigh

Iliotibialis
Ilioextensorius
Iliofibularis

Muscles of the Forearm

Extensor ulnaris
Extensor radialis profundus
Extensor radialis superficialis
Palmaris metacarpalis
Flexor radialis
Palmaris superficialis
Pronator
Supinator

After making the observations on the external parts, skin the animal by cutting along the mid line of the back, being careful in removing the skin from the legs and from parts that might tear off. In skinning over the gills, care must be taken or they will pull off with the skin. Note the myotomes and the myocommata that divide them. Note the rows of slime glands on the tail and find the different areas on which they are located. Is there a lateral line in Necturus? Before starting the dissection, study the skinned animal as a whole and note the direction of the fibers in the muscle sheets. As you study the different regions, make tables showing the origin, insertion, and function of the muscles. Study the bones of the skull before starting on this section. Since the muscles are mostly attached to the skeleton, it is necessary to familiarize yourself with the skeletal region in which you are to work. Skeletons both dried and preserved in alcohol as well as charts should be provided for this part of the study.

MUSCLES OF THE SHOULDER GIRDLE

DRAWING 8. Make a drawing X 3 of the shoulder girdle, showing the attachment of the muscles.

The muscles are very clearly separated and require little dissection for demonstration. With a blunt instrument, make the necessary separation to show the origins and insertions. Use the right side for this work.

LATISSIMUS DORSI

Find the **humerus** and **scapula** for use as landmarks. Extending posteriorly and dorsally to the midline of the back is a large, fan shaped muscle, the **latissimus dorsi**. Determine its function by manipulating it in order to see its action on the humerus.

DORSALIS SCAPULÆ

This vertical, **scapular muscle** is immediately anterior to the **latissimus dorsi**. It is band like with an extensive origin on the **scapula** and **suprascapula**. It is inserted on the humerus.

CUCULLARIS

This muscle is inserted along the anterior edge of the **scapula** and **suprascapula**, anterior to the **dorsalis scapulæ**. It has a double origin from the **fascia** of the midline of the back.

OMOHYOID

The **omohyoid** is ventral to the **cucullaris** and extends diagonally forward. It originates in the **epibranchial** region and is inserted on the **procoracoid**, just posterior to the scapula.

RECTUS SUPERFICIALIS HYPOBRANCHIALIS POSTERIOR

This muscle is inserted on the **procoracoid**. It originates on the **myocommata** and proximal end of the first **epibran-**

chial. It parallels the **procoraco-humeralis** and is just dorsal to it.

Procoraco-humeralis

As indicated by the name, this muscle extends from the **procoracoid** to the **humerus.** It is parallel and just ventral to the **omohyoid.** The cartilage of the **procoracoid** is seen extending slightly anterior to the end of the muscle.

Supracoracoid

On the ventral side of the animal, locate the **procoraco-humeralis.** Extending to the median line and slightly covered by the large **pectoralis** is this spindle shaped muscle, extending from the humerus to the coracoid cartilage. Loosen the **pectoralis** slightly so as to see its origin and insertion.

Pectoralis

From the head of the humerus, a large fan shaped muscle extends to the **linea alba.** The origin is continued far posteriorly. Loosen the muscle and manipulate it so as to see its effect on the humerus and the girdle.

Loosen the latissimus dorsi and cucullaris, thus exposing the muscles of the inner face of the scapula and girdle.

Drawing 9. Make a new copy of the drawing of the girdle and place on it these muscles of the inner side.

Serratus magnus

When the **latissimus dorsi** is removed, a thin band of muscle is seen extending posteriorly and ventrally from the face of the suprascapula. It is very small and quite unlike the muscle of the same name in the mammals.

Levator scapulæ

Remove the cucullaris by cutting through the middle and deflecting thus exposing the levator scapulæ. It is a small

muscle that extends from the inner face of the supra-scapula, anteriorly to the skull. Follow this muscle to its origin.

MUSCLES OF THE FORE LIMB

Triceps

This is a variable muscle that might better be named the **quadriceps**, since it generally has four heads. It covers the entire dorsal face of the **humerus** and has heads on the **humerus, scapula** and **coracoid**. The first of these is double thus making four heads for the entire muscle, which is inserted on the olecranon process of the ulna. Loosen the muscle at its insertion and separate the heads. A superficial median head takes origin from the base of the *scapula*. Beneath this, a second slip takes origin from the anterior face of the head of the **humerus**. Laterally, one head originates on the outer side of the **humerus**, while an inner slip originates on the posterior border of the **coracoid**.

Biceps

Ventral to the **triceps** and on the opposite side of the **humerus**, the **biceps** occupies practically the same position as the muscle of the same name does in the mammals. It originates on the proximal end of the **humerus** and is inserted on the outer face of the proximal end of the **radius**. A few fibers may come from the **coracoid**. The insertion is seen better after the removal of the muscles of the lower arm.

Coraco-brachialis

This muscle is on the anterior or ventral face of the humerus, paralleling the biceps but on the inner side of the arm. It originates on the **coracoid** and is inserted on the inner, distal part of the shaft of the humerus.

Cut through the coraco-brachialis and note the smaller muscle beneath it. This is the **coraco-brachialis brevis.** *For convenience, remove the girdle from the right side of the animal and work out the rest of the muscles from the detached limb.*

Scapulo-humeralis

On the inner side of the girdle, note the small muscle that originates from the posterior notch of the **coracoid,** and from the posterior edge of the **scapula.** It extends to the humerus where it is inserted on the inner face of the distal end. To see the origin and insertion of this muscle, the **triceps** should be dissected loose at the proximal end.

MUSCLES OF THE CARPUS

Study the muscles of the back of the hand, and separate the three muscles that appear. The median muscle serves as a landmark.

Extensor metacarpalia

The origin is on the outer face of the distal end of the humerus, and the insertion at the bases of the **metacarpalia** where it ends in digitations.

Extensor radialis

This muscle is partially covered by the **extensor metacarpalia.** With this removed, the two slips of the **extensor radialis** are seen, an anterior and a posterior. The anterior is the larger and longer. It originates on the outer face of the **condyle** of the **humerus** and is inserted on the outer face of the **radius** and on one of the **carpal bones,** the **radiale.**

The posterior slip is shorter. It originates posteriorly to the other slip and is inserted on the radius.

Extensor ulnaris

At the posterior border of the **extensor metacarpalia** a portion of the **extensor ulnaris** can be seen. With the covering muscle removed, it is very evident on the posterior border of the limb. It originates on the outer face of the distal end of the **humerus** and on the **olecranon process** of the **ulna** and is inserted at the base of the **metacarpal** number four.

Supinator

When the **extensor metacarpalia** is removed, the fibers of the **supinator** are seen on the carpus. This muscle originates on the middle of the carpus and is inserted at the base of the first toe.

MUSCLES OF THE PALMAR SURFACE

As seen superficially, the **flexors** of the palm are three in number. The median is the **palmaris superficialis**, the anterior the **flexor radialis** and the posterior the **flexor ulnaris**. The last must be dissected loose with care as it is closely associated with the palmaris.

Palmaris superficialis

This is the large median muscle of the palm. Dissect it loose at the borders. It ends in the **palmar fascia**. The origin is on the condyle of the humerus.

Lift the palmaris superficialis, cut through at the middle and deflect. Four muscles can be seen with this dissection completed.

Flexor ulnaris

The origin of this posterior muscle is on the humerus. Extending distally it is inserted on the carpals at the base of the fourth toe.

Flexor radialis

This muscle arises on the humerus near the condyle and is inserted on the carpals near the bases of the first and second toes. The insertion is covered by the **pronator.**

Ulnaricarpalis

This small slip is seen extending out from under the **flexor ulnaris.** It originates on the ulna and is inserted at the base of the third toe.

Pronator

Originating on the ulna and extending diagonally, it is inserted on the carpals at the base of the first toe. The **supinator** is directly opposite it, on the other side of the limb.

Study the muscles of the anterior limb by sections. To understand the relations of the muscles in the anterior limb, make two cross sections: (1) *through the middle of the femur and* (2) *through the middle of the radius and ulna. Cut through with a sharp pair of scissors, making a smooth cut. A glass of small magnification is advantageous in examining these sections. If there is any trouble in identification separate the muscles and use the drawings already made as an aid in their recognition.*

MUSCLES OF THE TRUNK

The body or trunk muscles show many characteristics similar to those of the fish since the **myotomes** are distinct for the whole length of the body. In higher animals the **myotomes** and **myocommata** are absent, being evident in but a few muscles. The midline of the back divides the muscles into a right and a left side, while the **linea alba** separates them ventrally. Laterally a groove with rows or

patches of mucous cells, divides them into a dorsal **epaxial** and a ventral **hypaxial** series. Dissect into the muscle layer of the body.

DRAWING 10. Make a diagram showing the direction of the fibers of the different sheets.

What is the function of this distribution of the fibers?

MUSCLES OF THE PELVIS

DRAWING 11. Make a copy of the ventral view of the skeleton of the girdle, with the limbs attached to be used in showing the origins and insertions of the muscles. From the ventral face of the pelvic plate, a number of muscles are seen extending out to the femur and to the other bones.

PUBOISCHIOTIBIALIS

This posterior muscle of the pelvic region, covers the other muscle of the anterior part of the girdle, the **puboishiofemoralis externus**. It takes its origin from the pelvic plate and is inserted on the tibia and ventral surface of the foot. Note the **raphé** at about the middle of the muscle as this is a good landmark. Distal to the raphé, the muscle splits, a smaller slip extending to the fascia of the ventral surface of the foot. This muscle is sometimes called the **semimembranosus**, but it is really a part of the undifferentiated muscle mass in Necturus. Near the **raphé** a muscle is seen extending back to the caudal region. Dissect away the soft material around the cloaca to expose this muscle. This is an example of a muscle that has its insertion on another muscle, a rather uncommon condition. This tail muscle is called the **pyriformis** or better the **caudali puboischiotibialis.**

Separate the puboischiotibialis from the rest of the mass, cut it through at the raphe and deflect to the two sides.

Puboischiofemoralis externus

This is a large muscle with several slips that originate on the ventral face of the girdle. These extend to the femur and are inserted along the shaft. Note that the fibers run in different directions and that slips may be incompletely separated off from the main mass. If the posterior slip is deflected, a still deeper slip will be seen. This is called the **adductor femoris.**

Ventral View of the Thigh

This most anterior muscle which forms the border of the thigh is the **puboischiofemoralis internus.** The **pubotibialis** is next in order posteriorly. Then comes the **puboischiotibialis** and finally, the posterior, distal slip of the **puboischiotibialis** which extends from the **raphé** of the main muscle to the ventral surface of the foot, joining the fascia of this region.

Puboischiofemoralis internus

With the **puboischiofemoralis externus** removed, the outlines of the muscle become evident, extending to the midline of the dorsal side of the pelvic plate where it has a large origin. This can be seen to better advantage after the pelvic plate is removed, hence this observation is delayed until later in the dissection. The insertion is on the femur.

The muscle is divided into three slips. The anterior and largest slip originates on the median line of the pubis, the origin extending almost to the **puboischiac fossa.** After entering the body it spreads out fan shaped, curves around the ilium and is inserted along the whole anterior border of the femur. A second slip originates on the median line of the pelvic plate, immediately posterior to the anterior slip, curves around the ilium, joins the anterior slip and

is inserted on the femur, distal to the insertion of the first slip. The third slip originates in the puboischiac fossa and on the ilium, curves around the posterior border of the ilium and is inserted on the dorsal face of the femur, extending to about the middle of the bone. It is not quite parallel to the rest of the muscle, as it must diverge slightly to pass around the posterior side of the ilium. Some fibers come from the ilium itself. Get the details of this muscle after the removal of the girdle from the body.

Pubotibialis

Posterior to the **puboischiofemoralis internus**, this muscle is quite evident, although the insertion and origin are hidden. By a slight separation of the muscles the origin can be seen at the anterior edge of the **acetabulum** on the pubis where a tendon is formed. The insertion is on the proximal, ventral face of the tibia.

By sectioning the puboischiotibialis, it is possible to study the several muscles that are exposed by this operation.

Femoro-fibularis

After pushing the **pubotibialis** forward note this small muscle originating on the posterior face of the femur at about the middle of the bone. It extends out to the **fibula** where it is inserted on the proximal end.

CAUDAL MUSCLES

The three caudal muscles can now be dissected out on the ventral side. The outer muscle is the **pyriformis**, the inner the **ischiocaudalis** and the deeper central element the **femorocaudalis.**

Pyriformis

This is the outer of the three tail muscles of the tail. It originates on the **hæmapophyses** of vertebræ number

22-23-24. It is split and appears to be the origin of the **caudalifemoris.** The insertion is at or near the **raphé** on the **puboischiotibialis.**

Ischiocaudalis

The innermost of the three tail muscles originates on the **hæmapophyses** of the tail vertebræ, extends anteriorly, and is inserted on the ischium.

Femorocaudalis

The third and deepest of the tail muscles is seen by separating the other two. It extends anteriorly and is attached by a tendinous insertion on the femur at about one third of the distance from the head of the bone. These three muscles form the musculature of the tail being specialized out of the mass of muscle in this region.

MUSCLES OF THE BACK OF THE THIGH

Separate the muscles so that they are loose from one another and study the relations of this superficial group. Place the animal on its back with the legs at right angles to the body. The anterior muscle is the puboischiofemoralis internus, the second the iliotibialis, the third the ilioextensorius, the fourth the iliofibularis and the most posterior the puboischiotibialis. The landmark of the upper or dorsal surface of the thigh is the ilioextensorius. The puboischiofemoralis internus was described as a ventral muscle hence it may be omitted. The final study of this muscle is to be reserved until the pelvis is removed from the body.

Iliotibialis

This muscle, second from the anterior border of the thigh, is in front of the **ilioextensorius.** It originates on

the **ilium**, extends down the **femur** and is inserted by a tendon on the proximal end of the **tibia**, acting as an extensor of the leg. Follow the muscle from the origin to the insertion.

Ilioextensorius

The third muscle from the anterior border of the leg is quite large. It originates at the base of the ilium posterior to the origin of the **iliotibialis**, and extends along the posterior border of the thigh. After passing over the knee, it spreads out in an **aponeurosis** and joins the muscles of the lower leg, where it serves as an extensor.

Iliofibularis

This muscle is posterior to the **ilioextensorius** and is partially covered by it. It is a long, thin muscle that is mostly covered by the more anterior elements. Lift the **ilioextensorius**, find its origin and follow the muscle to its insertion on the fibula.

Cut through the iliotibialis and ilioextensorius in order to find the origin of the two muscles. Posterior to the puboischiofemoralis internus, are two slips of the same muscle, both of which are shorter than the anterior slip. Locate their insertion on the femur. The iliofibularis now shows completely and its origin and insertion can be determined.

MUSCLES OF THE LOWER LEG

The muscles of the lower leg have a great similarity to those of the anterior limb. Carefully dissect the muscles of the back of the foot.

Drawing 12. Prepare a drawing of the skeleton of the region for use as a basis for the locations of the origins and insertions.

Femoro-metatarsalis

There are three muscles on the dorsal face of the foot. The median of these is the **femoro-metatarsalis.** Note the origin and follow the muscle to the insertions between the metatarsals. Note how it is split to serve the tarsals. (A deeper slip is seen with further dissection.)

Extensor tibialis

The anterior of the three muscles is a heavy structure. To see this muscle it is necessary to remove the **femoro-metatarsalis** from its origin.

Extensor tibialis profundus

With the removal of the **femoro-metatarsalis** this slip is seen. Note the origin and insertion.

Extensor fibularis

It is completely covered by the deep slip of the **femoro-metatarsalis.** With this dissected away it is plainly seen.

Supinator

This small muscle originates on the *fibula,* distal to the extensors, and extends diagonally across the *tibia.*

MUSCLES OF THE SOLES OF THE FEET

Plantar superficialis

This is a short, heavy muscle that originates on the femur, extends distally and blends with the fascia of the sole of the foot. *Determine the origin, cut through at the distal end of the muscle and deflect to see the muscular elements underneath.*

Plantaris profundus

With the deflection of the superficial plantar, this large muscle is seen extending diagonally across the foot. Note the relation of this muscle to the superficial slip.

Cut through the plantaris profundus and identify the two muscles that are seen extending under it.

Fibularis tarsalia

This is a small, thin muscle that originates on the fibula and is inserted on the tarsalia. Locate the points on the skeleton of the foot.

Pronator

A large, triangular muscle extends from the fibula, to the tibia and serves as a pronator.

Some of the smaller muscles of the foot and toes have been omitted.

After the other organs have been studied and drawn, remove the pelvic girdle and study the musculature that belongs strictly to this structure. This will give the connections between the girdle and skeleton and between the girdle and legs.

MUSCLES ATTACHED TO THE PELVIC GIRDLE

Ventral Side	Dorsal Side
Puboischiofemoralis externus	Puboischiofemoralis internus
Puboischiotibialis	Ischiocaudalis
	Ischiotibialis
	Ilioextensorius
	Iliofibularis
	Ischiofemoralis
	Rectus abdominus

Puboischiofemoralis internus

With the removal of the pelvis from the body, the origin of this muscle is apparent extending to the midline of the

dorsal side of the pelvis. Parts of the muscle separate, curve around the **ilium** on both sides and join after passing around this bone.

Ischiocaudalis

This tail muscle originates on the **tail vertebræ** and is inserted on the dorsal side of the **ischium.**

Ischiofemoralis

A short muscle of small size is seen after the removal of the body wall. It originates on the **ischium** and is inserted on the proximal end of the **femur.**

MUSCLES OF THE HEAD

Drawings 13, 14, 15. Make three drawings of the head from the dorsal, lateral and ventral sides, showing the musculature.

Study the distribution of the muscles that are to be seen and learn their names. You should recognize four head muscles, the temporals, masseter, mylohyoid and ceratohyoid. In all of these dissections use the handle of the scalpel. Dissections should consist of a separation rather than a cutting of parts.

DISSECTION OF THE MUSCLES OF THE HEAD AND THROAT REGION

Masseter

The dorsal view of the head shows two large muscles, a median pair the **temporals** and a lateral pair, the **masseters.** *First dissect loose the masseter from the left side and work out its origin and insertion. Note the names of the bones on which it originates and the type of the insertion on the mandible. Trace the relations of this insertion to that of the temporalis.*

Temporal

Loosen the **temporalis** *of the left side and follow it to its insertion on the jaw, just posterior to that of the masseter. Find all of the bones on which it originates.*

Mylohyoid

Turn the animal to the ventral side and examine the large muscle that covers the ventral region. Draw and show the different direction of the fibers. What is the use of this muscle? Remove the **mylohyoid** *by splitting along the midline and deflecting.*

Digastric or Depressor mandibulæ

Look on the side of the head for this **depressor** of the jaw. It is posterior and ventral to the large **masseter.** There are two muscles in this region, the **digastric** and the **ceratohyoid,** the **digastric** being the more dorsal. *With a blunt dissecting instrument, separate the digastric from the ceratohyoid which is just ventral to it. Work out the origin, insertion and function.*

Ceratohyoid

Ventral and posterior to the digastric is a large muscle, the **ceratohyoid externus.** Find the origin, insertion, and determine the function.

With the **mylohyoid** removed, the muscles of the throat are easily seen, consisting of a median band of muscles, the **geniohyoids,** the **ceratohyoids** extending from the posterior angles of the skull, and the more posterior **sternohyoids.**

Geniohyoids

This is a pair of median muscles, so closely appressed to one another that they work as one muscle.

The origin and insertion are easily seen. What is the action?

Cut across the **geniohyoids** *and deflect the* **ceratohyoids** *to show the other ventral muscles.*

Ceratohyoid internus

This small fusiform muscle is beneath the anterior end of the **ceratohyoid externus**. It is one of the hyoid series.

Sternohyoid

Ventral to the **geniohyoids** and also joined in the median line are the **sternohyoids**. They are large, flat muscles that help in the formation of the musculature of the body. The insertion is seen to best advantage from the inner or dorsal side of the visceral apparatus. Note that a small slip of this muscle is attached to the shoulder girdle between the **procoraco-humeralis** and the **supracoracoideus**. Turning back to the head again, note the large muscles of the back that are attached to the posterior end of the skull. These muscles are not much specialized in the Urodeles.

Levators

On the back of the neck in the area marked off by the **masseter** and **ceratohyoid**, are two small muscles that are connected with the elevating of the gills. The anterior is the **levator arcuum branchiarum** and the posterior is the **levator branchiarum.**

The **levator arcuum branchiarum** originates on the skull and is inserted on the superior angle of the **branchial cartilage.**

The **levator branchiarum,** the second of the **levators** is inserted at the base of the gills. It is fan shaped, lighter, and more delicate than the other.

Constrictor arcuum

On the ventral side of the skull, deflect the ceratohyoids outward and press out the branchial arch in order to see the constrictors.

There are three of these small **constrictors**. The more anterior is between **epibranchials** 1 and 2, the second between **epibranchials** 1 and 3 and the third and smallest is between **epibranchials** 2 and 3.

Depressor arcuum branchiarum

Ventral and lateral to the **constrictors** this muscle is inserted on **epibranchial** 3. It depresses the gills. Note its origin on the floor of the visceral skeleton. It is seen better from the dorsal side of the visceral arch. After the depressor has been removed, the dorsal side of the **sternohyoid** is seen beneath it.

THE BLOOD VASCULAR SYSTEM

The blood vascular system is very much like that of the shark, but with additional adaptations to land life. The lungs have not assumed much importance, and in consequence the heart is of the fish type with the **atrium** doubled by a **perforate septum.** The heart of Necturus has some similarity to that of Ceratodus, a lung fish, in which there is a partial separation of the **atrium.** In Necturus the blood that goes from the heart to the gills does not return again, but goes directly to the systemic vessels by way of the efferent arteries. The blood from the lungs enters the left side of the heart through a single vessel, since the **pulmonary veins** join near the heart. The **septum** between the *atria* is complete but it is fenestrated so that it is not a perfect membrane. The **truncus** is not divided by a ridge or flap as in the frog but is a straight tube. The **conus arteriosus** is supplied with **pocket valves** and the **bulbus** is enlarged to serve as an equalizer to keep the pressure constant. The changes in the arterial system consist of the reduction of the **aortic arches** from five to three, and the development of the **pulmonary artery** from the sixth. Thus the sixth arch forms the **pulmonary artery,** the fourth the **systemic arch** and the third with a part of the **anterior arches,** forms the vessels leading to the head. The changes in the veins are more radical. A new vein the **postcava** forms a connection between the **right subcardinal** and the **sinus venosus,** thus taking some of the blood from the kidneys. The **lateral veins** have joined to form a single, **ventral abdominal,** changing the anterior connection so that instead

of entering the **common cardinal**, they now enter the **hepatic portal**. By this new connection blood from the posterior limb has two outlets, one through the **abdominal** to the **hepatic portal** and a second through the **postcava**.

VENOUS SYSTEM

1. Blood returning from the head comes through the **external** and **internal jugulars** to the common cardinal or the ductus Cuvieri.

2. Blood from the anterior limb comes through the **subclavian** vein to the **ductus Cuvieri**.

3. From the posterior end of the body, the blood comes through the following vessels:—

(a) Lateral veins
(b) Posterior cardinals
    Connected with the renal portal system
    Connected with the postcava by anastomosing vein
    Connected with veins from the ovary and testes
(c) Postcava (Hepatic sinus at anterior end)
    Two hepatic branches lead into it
    Blood from the kidney through the venae reheventes
(d) Blood from the tail
    Through caudal veins to kidneys
    Pelvic veins from the legs
(e) Hepatic Portal System
    Blood from the anus and pelvis
    Splenic
    Gastric, two branches
    Mesenteric from the intestine

In an injected specimen study the systems as found in the body cavity.

Drawing 16. Make a diagram of both the arterial and venous systems by piecing together the parts as worked out.

The systems may be studied so as to preserve most of the parts, by taking it section at a time, whereas the complete dissection of the system would destroy the rest of the animal for other study.

Postcava

The large vessel, returning blood from the kidneys and liver, is the first to be studied. *Place the animal on its back, turn the liver to the animal's left and gently separate the organs on the midline of the back, so as to see the large vessels between the kidneys.* This vessel is formed by numerous venæ reheventes coming from the kidneys and from the sex organs. The vein enlarges as it reaches the anterior end of the kidneys bending ventrally to reach the dorsal surface of the liver. *Follow it to the hepatic sinus by picking away part of the liver substance.* At the posterior end, near the entrance into the liver, the postcava receives a vessel the hepatic, from the posterior end of the liver. At the anterior end of the liver, it receives another branch from the anterior lobe of the liver. These veins come from the liver. The **hepatic sinuses** enter the **sinus venosus** and **right atrium.**

Hepatic Portal

This system brings the blood to the liver, from the following veins, **abdominal, splenic, gastric,** and **mesenteric.** *Move the liver to the right side of the animal and note the gastric vessels coming into it.* There are usually two entering it from the anterior end of the stomach, about a centimeter apart. In the region of the pancreas the veins enter from the spleen, stomach, pancreas, and intestines. Locate the spleen and follow the splenic vein through to the hepatic portal. Small veins coming from the pancreas are added. The **mesenteric** comes from the intestines.

Abdominal

The **abdominal** is found in the ventral wall of the body. It receives blood from the pelvic veins and the anal region.

Turn back the body wall and follow this vessel from the pelvis to the point where it turns dorsally and enters the liver, joining the hepatic portal.

Renal Portal System

Trace the renal portal system posteriorly along the kidneys determining the anterior and posterior ends of the system. Posteriorly the caudal connects with the vessels, and laterally the vein from the posterior limb. The renal portals give off a series of **venæ advehentes** which lead the blood to the kidneys.

Posterior Cardinals

The renal portals are continued forward as the posterior cardinals. They lie on each side of the dorsal aorta, close to the dorsal midline of the body. They enter the **ductus Cuvieri** or the common cardinal. Near the curve in the postcava where it enters the liver, there is a small anastomosing Y vein which connects the **two cardinals** and the **postcava.**

Lateral Vein

This small vein may be seen by cutting into the lateral line at the anterior end of the body. It enters the ductus Cuvieri. It is made up of branches from the abdominal wall. Trace it to the heart.

Pelvic Veins

Split the pelvis on the ventral side and identify the pelvic vein which is usually paralleled by the pelvic artery. Before going through the body wall it divides into two branches.

Pulmonary

Examine the lungs and locate the two pulmonary veins on the inner side of these organs. Follow them to the

septum transversum, where they unite to form a single vessel and enter the left auricle.

Veins Anterior to the Septum Transversum

Dissect into the anterior part of the sinus venosus and locate the ductus Cuvieri. Several vessels are to be traced to this region, the **posterior cardinal, lateral vein, jugular, submaxillary,** and **subclavian.** The anterior end of the **post cardinal** is seen extending posteriorly. It can now be added to the drawing. At this stage of the dissection work out the vessels connecting with the heart, reserving the heart for later work.

The study of the afferent vessels is taken up at this point to avoid waste of material. With a slight removal of the muscles at the side of the **truncus arteriosus,** the afferent vessels appear. *Trace these to the gills and note their distribution.* After the removal of the skin from the head and gills, the **carotids** may be dissected out at their origins, with little disturbance to other parts.

External Carotid

Remove the skin from the back of the head and the bases of the gills. The **external carotid** extends anteriorly between the **masseter** and the **ceratohyoid.** It is large in comparison with the **internal carotid.** A short distance from its origin, it branches into several small vessels which supply the orbit, eye, nose, and a part of the jaw muscles. Determine the roots of these twigs.

Internal Carotid

Divide the mylohyoid along the median line so as to expose the roof of the mouth. Cut through the symphysis of the mandible so that this region may be fully explored. Dissect away the skin from the roof of the mouth and

locate the vessel extending forward from the first efferent **branchial artery.** *This is the* **internal carotid.** *Note the parts supplied by this vessel.*

Vertebral Artery

At this point in the dissection the **vertebral artery** is easily determined. It extends anteriorly from the base of the roots of the aorta. It is seen as a branching artery mesial to the internal carotids. A small branch goes to the posterior along the vertebral column.

The roof of the mouth is to be studied when the cut is made to locate the internal carotids and the internal jugulars. Spread the jaws apart and note the structures of this region.

Small conical teeth are located on the margins of the jaws. *Break off a tooth and examine it with a lens of low power, one of three diameters magnification is sufficient for this purpose.*

Locate the **external nares** *and probe through to the* **posterior nares.** They are external to the last row of teeth. Compare the position of posterior nares with those of the frog. The gill slits are two in number and are found on the side of the pharynx. These slits have toothed projections like those found in fishes. The gills, which are external, are attached to the cartilaginous gill arches. These external gills are not homologous with those of fishes. To avoid a destruction of parts, study the lower part of the pharynx and glottis after the dissection of the blood vessels.

The veins that open into the **ductus Cuvieri** are the **internal** and **external jugulars,** the **posterior cardinal,** the **lateral,** and **subclavian.**

To follow the jugulars, it is necessary to remove the lining of the inside of the mouth and to expose the bases of the gills on the dorsal side.

External Jugular

Turn the animal on its back and expose the base of the gills where the skin is already removed. The large external jugular sinus is exposed paralleling the external carotid. Follow it posteriorly to where it is joined by the internal jugular and the subclavian. It enters the ductus Cuvieri. Anteriorly it branches and breaks up into several smaller vessels that supply the nose, eye, oral cavity, and the anterior part of the jaw. The enlarged base of the **external jugular** forms the **jugular sinus.**

Internal Jugular

Examine the roof of the mouth and locate the roots of the aorta. The **internal jugulars** are dorsal to these and follow the roots anteriorly. They return the blood from the roof of the mouth and brain to the **anterior cardinal.**

Subclavian Vein

Remove the skin from the back of the front limb and locate the brachial branch of the subclavian. Trace it to where it enters the subclavian. At the shoulder region, it is joined by the cutaneous vein. The **subclavian** enters the **anterior cardinals** along with the **jugulars.**

ARTERIAL SYSTEM

The arterial system is made up of the following parts:

Heart and truncus arteriosus
Afferent vessels: first afferent artery
second afferent artery
third afferent artery
Efferent vessels: first efferent artery
second efferent artery
third efferent artery

The external and internal carotids arise from the first efferent artery. The three efferent vessels join to form the roots of the aorta.

The vessels coming from the aorta are:

Pulmonary artery from the roots of the aorta
Vertebral artery from the roots of the aorta
Subclavian
    Cutaneous
Small spinal arteries to the body wall
Gastric artery
    Splenic
Coeliaco-mesenteric
    Splenic
    Hepatic
    Coronary
    Intestinal arteries
    To ovaries and testes
Posterior mesenteric arteries
    Numerous branches to intestines
Iliac artery
Small artery to anal gland
Small artery to the caudal muscles

The aorta ends in the tail as the caudal.

An efferent artery takes the blood from each of the three gills to the aorta. Remove the skin from the dorsal side of the gills and locate the three dorsal vessels. The external and internal carotids extend from the first efferent vessel. A small anastomosing vessel connects the first and second **efferent arteries**, while the second and third **efferent arteries** form the roots of the aorta.

Subclavian Artery

Dissect in on the ventral side of the leg to find the subclavian artery extending along it. If the specimen is well injected, it may be followed to the individual muscles. The cutaneous extends to the pectoral muscles and to the posterior part of the body. Follow the subclavian back to its origin a few millimeters posterior to the joining of the roots of the aorta.

Gastric

This artery comes off at a distance of about 50 mm. from the origin of the aorta. It sends branches to the spleen and stomach.

Coeliaco-mesenteric

This artery sends branches to the stomach, intestine, spleen, pancreas, and liver. Gently separate the viscera so as to see the origin from the aorta. It comes off about 70 mm. from the origin of the aorta. Trace it to determine the branches to the parts named.

Posterior Mesenteric Arteries

These supply the intestines, caudad to the origin of the coeliaco-mesenteric axis, sending off a number of mesenteric arteries to supply the intestine. Count the number in your specimen.

Iliac

This artery supplies the hind leg, sends a branch anteriorly to the cutaneous, and one to the cloaca and bladder. Cut through the pelvic arch and the vertebræ for a distance of about 40 mm. caudad to the anus. The **iliac** comes off from the aorta about 20 mm. cephalad to the anus. It divides into three branches before entering the body wall. The first branch, the **epigastric**, extends anteriorly and anastomoses with the cutaneous. The second branch, the **femoral**, extends along the ischium and enters the leg at the head of the femur, where it branches to supply the muscles of the leg. A smaller posterior branch, the **hypogastric** branches from the iliac and extends caudad to supply the cloaca and bladder. Trace these three branches to the fields that they supply.

Renal and Gonad Arteries

The kidneys and gonads are supplied by numerous short branches from the aorta at their level. These arteries are numerous, short and direct.

Caudal Artery

Below the anus, the aorta becomes the caudal artery. It is seen by cutting through on the mid-ventral line at the time when the girdle is cut through to expose the iliac. The caudal extends in the hæmal arches posteriorly along the vertebræ, giving off branches to the anal gland and the caudal muscles.

HEART

After the other organs have been studied, the heart may be removed to complete the work on circulation. While the heart is in position, study it from the ventral side. Examine the **pericardial cavity, sinus venosus, septum transversum, truncus arteriosus** with its two parts, the **conus** and **bulbus**, the **Cuvierian duct, atria** and **ventricles.**

Drawing 17. Make a drawing of the heart in position to show these structures.

Remove the heart from the **pericardium** with plenty of the body wall. First note the thin **sinus venosus** emptying into the right atrium.

Sinus Venosus

The sinus receives blood from the large **hepatic sinuses,** the posterior cardinals, and anterior cardinals. The opening into the right atrium is large and oval in shape.

Pulmonary

The pulmonary veins join at the posterior side of the heart and enter the left atrium by a small aperture. It is

much smaller than the opening into the right atrium. Cut an opening into the atria so as to expose the inside. Note the **inter-atrial septum** and the **fenestrations** that make it incomplete.

Atrioventricular Opening

The atria open into the ventricle by a single passage protected by valves. The blood from the two atria is forced through into the ventricle at the same time. This opening is valved and supplied with muscles to regulate it. Which atrium is the larger?

Ventricle

The walls of the ventricle are to be slit so as to show the **atrioventricular** opening and also the opening into the truncus. The walls of the ventricle are heavy in comparison with the thin walls of the atria.

Truncus Arteriosus

Slit the truncus from the ventricle to the efferent vessels. Is there a **septum** dividing it into two parts as in the frog? Note the series of valves that prevent a return. What is the type of valve found here? The enlargement of the **truncus** is a pressure equalizer so that there may be a steady stream of blood going to the gills. The part of the **truncus** with valves is called the **conus arteriosus,** while the enlarged part is the **bulbus arteriosus.**

THYMUS AND THYROID GLANDS

Thymus

This large gland is found on the dorsal side of the head above and mesial to the mandibular articulation. It is located in the angle formed by the posterior part of the masseter muscle and the mesial side of the **ceratohyoid externus**. A slight removal of the fascia and superficial blood vessels may be necessary to expose it fully.

It is reddish gray in color and quite different from the surrounding muscle tissues in this respect. When well developed, it measures about 7 mm. long and 5 mm. wide. It extends ventrally between the muscles for some distance.

Make a thin slice with a razor blade and observe the characteristics of the gland. If studied with a magnification of X 25, numerous small cells, together with occasional oval, nucleated blood cells will be seen. The small cells are leucocytes. It is desirable to have prepared slides for the observation of the microscopic structure. Compare its structure with a similarly prepared slide of the thyroid.

Thyroid

The thyroid is on the ventral side of the branchial arches in Necturus. To see it in position, spread apart the **ceratohyoid externus** and the **sternohyoid** muscles until the distal end of the first **ceratobranchial** can be seen clearly. The gland is a small, thin, follicular disc that lies on the distal end of the first **ceratobranchial**, spreads over the proximal end of the first **epibranchial** and covers the small second **ceratobranchial**. The gland rests on a sur-

face that is inclined mesially and dorsally. It is difficult to see because of its similarity to the cartilaginous material on which it lies but the follicular structure will distinguish it from cartilage. The thyroid is about 5 mm. long and 2 mm. wide with a thickness of about a millimeter. Carefully remove the disc and place in a watchglass for observation under a X 15 magnification. If desired it can be dehydrated, stained and cleared. If prepared slides are available, more of the structures can be shown. Note the large follicles lined with a single layer of cells and full of colloid material. Count the number of follicles.

VISCERA

These directions are given as though no other work had been done on the animal because of the fact that it may be desirable to start with the digestive organs if the circulatory system is not included in the dissection.

Make a median cut along the linea alba, taking care not to cut the organs beneath the body wall. This cavity exposes the **pleuro-peritoneal cavity** which contains the lungs, digestive organs, urogenital organs, and other structures. It is lined with **peritoneum**. Measure the length of the cavity and get the position of the organs in this length. Spleen 22-70. would indicate that the anterior of the spleen was 22 mm. from the anterior end of the cavity, and the posterior end 70 mm. from the anterior end.

Liver

The large **liver** is on the ventral side of the body and usually forces itself out, when the body wall is cut through. It is fastened to the body wall by the **mesohepar**, one of the **mesenteries**. Find the relative length of the liver in the cavity. Look between the lower and median lobes for the **gall bladder**. It is large and easily seen. Follow the gall bladder and its duct to the liver and to the end of the **duodenum**. Note the lobes of the liver. Push the liver to one side and note the parts of the digestive tube.

Pancreas

The lobate, whitish, **pancreas** is applied to the duodenum. It sends an arm forward and one along the intestine.

Note where its duct enters the lower part of the duodenum.

Spleen

The **spleen** is a dark body, that is attached to the stomach by the **gastrosplenic membrane.** Show this in the drawing of the digestive system. **The spleen is not a part of the digestive system.**

Lungs

Posterior to the stomach, note the **two lungs.** They are small and are usually collapsed and empty of air. Insert a small blow pipe and inflate them to see their size. Note the length of the lungs and chart their position in the **pleuro-peritoneal cavity.** Follow the lungs forward and find the **glottis.**

If the specimen is a female, the oviducts may be seen extending forward under the other organs along the back wall.

Split the digestive tract from the anterior end of the stomach to the intestines. Note the ducts that enter the system and the different character of the lining in the different parts.

Membranes

There are several membranes. Their position is given in the table below.

Mesohepar, from the liver to the ventral wall of the body
Gastrohepatic, from the liver to the stomach
Mesogaster, from the stomach to the dorsal wall
Gastrosplenic, from the stomach to the spleen
Hepato-duodenal-omentum, from the liver to the intestine
Mesorectum, posterior part of the intestine to the body wall

Drawing 18. Use one of the specimens to make a drawing of the entire digestive system to show the relative length and position of the different parts.

If two specimens are provided, an injected and an uninjected, the study of the vascular system may be postponed until the work on the body cavity is completed. If only one specimen is provided, then the vascular system must be worked out with the other systems.

Pull the digestive system to one side and remove it, thus exposing the urogenital system.

UROGENITAL SYSTEM

FEMALE UROGENITAL SYSTEM

Ovaries

The **ovaries** are elongate sacs extending along the body wall and usually filled with eggs of different stages, depending upon the season of the year and the age of the individual. The **ovary** extends from 70 mm. to 170 mm. of the length of the body cavity. Dorsal to the ovary the **mesovarium** attaches it to the dorsal wall of the body. Note the sac like shape of the organ.

Dorsal to the ovary are the much convoluted oviducts or **Müllerian ducts**. They extend the whole length of the body cavity. How do the eggs get into these oviducts? The anterior end is fastened to the dorsal wall of the anterior end of the cavity. This part of the duct forms the **ostium tubæ**, which is a funnel shaped opening. Find this opening. The oviducts open into the cloaca by two papillæ. Split the cloaca and find the two **papillæ**. They are quite evident.

Mesonephros or Wolffian Body

The **mesonephros** of the Urodeles is the type of kidney found in the fishes and amphibia. It consists of elongated organs that start as metameric structures, but later lose the matemerism as development goes on. The contact between the organ and the blood vessels is much closer than in the **pronephros**. The unit of structure consists of **Bowman's capsule, convoluted tubules** and a **nephrostome.**

In the males the anterior end of the **mesonephros** is utilized to carry away the sex products. It is supplied with **vasa efferentia** which connect with the tubules of the mesonephros and thus get to the **mesonephric duct.** The upper and anterior end of the organ is entirely taken over for this purpose, so that the posterior end only, acts as an **organ of excretion.**

In the females the **Müllerian duct** or oviduct serves for the purposes of carrying away the eggs so the mesonephros is no longer used in this way and carries nothing but the products of the organ itself.

The mesonephroi extend along the body cavity just dorsal to the oviducts and between them. The **ureter** is a very delicate tube to be seen at the lateral border of the mesonephroi. It extends posteriorly and opens into the cloaca. Remove the cloaca and trace the ureters to the wall of the cloaca. A **tubular urinary bladder** is to be found on the ventral side of the cloaca. It is thin and usually empty.

DRAWING 19. Make a drawing showing the parts of the female urogenital system.

MALE UROGENITAL SYSTEM

TESTES

The **testes** are two oblong bodies about 50 mm. in length. They are dorsal to the intestine and fastened to the body wall by the **mesorchium.** The outlet from the testes the **vasa efferentia** passes to the mesonephros, where after going through the tubules, it comes to the **Wolffian** or mesonephric duct and utilizing this, passes to the **cloaca.** The number of the **vasa efferentia** should be noted.

Mesonephros

The long mesonephroi extend along the dorsal wall of the body cavity. On the lateral border the convoluted Wolffian duct is very distinct. Trace its entrance into the cloaca if possible. It must carry the waste from the mesonephros as well as the **seminal fluid.** A small elongated, sac like body, the **urinary bladder,** should be identified.

Drawing 20. Make a drawing showing the parts of the urogenital system of the male.

NERVOUS SYSTEM

This very complicated system may be studied in its gross structure for the coarser points, but to understand anything of the finer structure, histological methods must be applied. The morphological unit of the system consists of a modified cell called the **neurone**. It is a specialized cell consisting of a cell body with connecting fibers that connect or rather associate it with other neurones of the rest of the system. Nerve cells should be studied in prepared slides so that their structure may be understood. The whole system consists of a multiplication of these units in their many forms. They are the units of structure but not the physiological units of the system. The physiological unit consists of two or more, of these cells consisting of an **effector, receptor** and an **adjustor**. These make up a simple reflex unit and are the basis of the whole system.

The development of this system has been a long one historically and to understand it thoroughly, it must be approached from both the embryological and histological sides. The development of the parts must be taken up with the reason for the development. Each sense has associated with it, centers in the system that are devoted to that one sense. To keep the machine harmonious, there must be interconnections, so that in a brain as simple as that of Necturus, the complication has already reached formidable proportions.

The nervous system is easily prepared for study in Necturus and all of the work taken up in this section can

be done on the regular formaldehyde specimens, after they have been used for the other parts of the study.

To study this part of the nervous system, cut the head from the body, taking about 20 mm. of the body with it. Place this in a solution of 10% nitric acid for two or three days to decalcify the bone. Before using, soak for a few hours in running water to remove some of the acid from the tissues. If the instruments used are oiled slightly, they will not be seriously injured by the action of the acid.

OUTLINE OF THE NERVOUS SYSTEM

The nervous system consists of the following parts: (1) brain and cord, (2) peripheral system consisting of the nerves and the autonomic system, (3) the sense organs.

The **brain** and **spinal cord** are enclosed in bone for the most part, the brain in the skull and the cord in the neural arches of the vertebræ. The brain forms the main or centralized part of the system with cranial nerves and the spinal cord as conducting paths.

The **peripheral system** consists of two parts, the peripheral system proper consisting of the connecting nerves that conduct sensations to, and the motor impulses away from the central system. The **afferent sensory nerves** and the efferent or motor nerves, take this part. Closely associated with this system and anatomically a part of it is the **sympathetic system** which supplies impulses to the viscera, blood vessels, and to other parts that need automatic regulation.

END ORGANS AND SPECIAL SENSES

The end organs of the nervous system are located in the skin as special sense organs and in other parts of the body

where they are needed, either on the exterior or in the interior. The sense organs of the skin can be studied only in specimens prepared for histological examination. The special senses are the nose, eye, ear, together with a number of other senses that are not so easily studied.

Nose

The **nose** is supplied by the olfactory or first cranial nerve. The nerve spreads out fan shaped in the nose region to serve this organ. The narial passage leads posteriorly to the back part of the roof of the mouth and external to the splenial teeth.

Dissect out the nose and determine the shape of the cavity.

Eye

The **eye** is rather small since the animal is more or less of a bottom feeder. After the skin is removed from the head, study the eye in position. A sheet of muscle located between the eyeball and the skull protrudes the eye, while a **retractor bulbi** draws it into the head.

Dissect around the eye so as to see the muscles clearly.

Drawing 21. Make a drawing showing these muscles in position.

They may be named from their position on the eyeball. Try these muscles by pulling gently to see their effects in moving the eyeball.

After the muscles have been determined in position, loosen them from the skull and remove the eyeball. Turn to the inner side and make a drawing large enough to show the muscles in position on the eyeball.

The muscles of the eye are six in number with an additional **retractor bulbi**. The **rectus superior** is located at the anterior end of the eye; the **rectus inferior** at the posterior end; the **rectus externus** at the outer edge of the ball; the **rectus internus** on the inner edge; the **superior**

oblique on the inner upper border; the **retractor bulbi** is around the optic nerve and serves to retract the ball. It opposes the **levator sheet** of muscle under the ball which elevates it slightly.

Study the eye and note the **cornea**, the clear layer covering the outer face, the shape of the **pupil** and **iris**. Make a median cut through the eye, dividing the eye into a dorsal and ventral half, immerse in water or alcohol and study the following parts.

The **ora serrata** is the wavy line that marks the outer limits of the **retina**. The two chambers of the eye are the space in front of the lens which is called the **anterior chamber** and the space between the iris and lens which is called the **posterior chamber**. The retina can be studied only in specially prepared slides.

Ear

The ear of Necturus is not difficult for dissection and may be used if desired.

In a specimen from which the brain has been removed, find the otic capsule and pare down the dorsal side until the cavity is reached. This capsule is largely cartilage and is not difficult to cut away, thus exposing the **semicircular canals** of the ear. These canals are imbedded in cartilage and bone and must be freed for study. There are three canals an **anterior, posterior** and **horizontal**. The lateral or horizontal is more ventral than the other two. The cavity exposed is the vestibule, which is filled with endolymph. The whole capsule may be removed and placed in a glass dish for study.

The three canals are supplied with **ampullæ** where they enter the **utriculus**. At the anterior end of the ear, the ampullæ of the lateral and anterior canals are to be noted. The ampulla of the posterior canal is located at the posterior end of the utriculus where the canal enters it.

The **vestibule** is divided into two parts, the **utriculus** and **sacculus.** The **utriculus** is the dorsal sac, into which the canals enter. The **sacculus** is the ventral sac. The sacculus is very shallow and indistinct and contains the otolith or ear stone. When the ear is removed from the head this stone can be seen in position if the light is directed through it from below.

DRAWING 22. Make an enlarged drawing of the otolith.

The **auditory** or the **eighth cranial nerve** supplies the parts of the ear. Before the capsule is removed for study note the auditory nerve where it comes through the skull and branches to supply the vestibule and canals. In decalcified specimens the nerves are easily seen and can be followed to the ampullæ, utriculus and sacculus.

If desired, some specimens may be cleared in one of the clearing agents to make the nerves more distinct. The ear has no **external meatus** but ends blindly. The **stapes** and **columella** extend out from the fenestra vestibulæ and articulate with a projection on the squamosal. It is probable that the most important function of the ear in the Urodeles is equilibrium, with the detection of sound as a secondary function.

BRAIN

After soaking the skull in nitric acid (10%) for two or three days, the bones become soft and are easily cut away thus exposing the brain on the dorsal side. First remove most of the muscles and then with a sharp scalpel shave away the dorsal surface of the skull until the brain cavity is reached. Complete the exposure until all of the brain is visible. The cranial nerves are plainly seen and need little further dissection to show the roots. To show the course of the nerves and their termination, more careful dissection will be needed. Note the pigmented **pia mater** *covering the brain. Place a piece of the pia mater on a slide*

under a cover slip and examine under a low power to study the large pigment cells.

Drawing 23. Make a drawing of the dorsal side of the brain X 6 showing the cranial nerves.

The large anterior lobes represent the **anterior lobe** of the brain. This is a combined **rhinencephalon** and **cerebrum.** There is no line of demarcation between them. A prominent **pineal body** or **epiphysis** extends forward between the lobes of the **cerebrum.** This flattens out on the inner side of the skull roof but does not penetrate it. The **diencephalon** does not show from the dorsal side. The median region or the **mesencephalon** is smooth and unmarked. The posterior end of this represents the **cerebellum,** although there is no external indication of its presence or its limits. The **optic lobes** are not so evident from the exterior view. A large triangular groove posterior to the cerebellum, is the **fossa rhomboidalis.** The **medulla oblongata** is posterior to the **mesencephalon** and contains the **fourth ventricle.** The medulla passes into the **cord with no dividing line.**

CENTRAL NERVE SYSTEM

Nerves of the Dorsal Side

The **nervus terminalis** is so closely associated with the olfactory in Necturus that special methods must be used to isolate it. It is practically internal in this form.

(1) The large **olfactory nerve** extends anteriorly from the anterior lobes to the nasal region where it spreads out fan shaped into a number of fibers that supply the nose. Dissect it free so that the branches in the nasal region can be seen. (2) The **optic nerve** extends out laterally from the **diencephalon** or **'twixt brain** and continues to the

eye. It is small and thread-like and must be traced carefully. Trace it to the eyeball. Note its origin on the ventral side of the brain. (3) The **oculomotor** is also a very small, threadlike nerve that extends out from the mesencephalon to the eye muscles. Its origin should be noted in the study of the ventral surface of the brain. (4) (6) **trochlear** and **abducens** do not appear as separate nerves in Necturus, but are incorporated in the **trigeminal** nerve from which they extend to the eye. Trace the branches of the fifth nerve to the muscles of eyeball. (5) The **trigeminal nerve** leaves the brain at the anterior end of the **fossa rhomboidalis,** extends out and expands into the **Gasserian ganglion.** The **ophthalmic branch** supplies the muscles of the eyes and a large second branch supplies the jaws. Follow the branches to the muscles of the eye and jaw. (7) The **facialis** leaves the skull with the auditory, just posterior to the exit of the trigeminal. It supplies the facial region and a part of the jaw musculature. A branch from the trunk extends to the **Gasserian ganglion.** Trace the nerve out of the brain case to the regions supplied. (8) The **auditory nerve** takes its exit from the brain with the **facialis,** but separates immediately and goes to the parts of the ear capsule to supply the inner ear. It can be followed to the canals with a glass of low magnification (X 3). (9) The **glossopharyngeus** comes from the brain, just posterior to the auditory nerve. It extends out from the medulla and joins shortly with the two roots of the **pneumogastric.** The **glossopharyngeus** supplies the gills, tongue and throat. (10) The **pneumogastric** or **vagus** arises by two roots from the medulla, joining with the glossopharyngeus to form a single trunk a short distance from the brain where the vagus ganglion is formed. It may be dissected out so as to expose it to view. This nerve supplies the heart and stomach.

Spinal Nerves

Follow the cord back to the spinal nerves and dissect out a pair to see their structure.

It will be noted that there are two branches, a dorsal and a ventral. The **dorsal** is sensory and supplied with a ganglion while the **ventral** is motor, and not supplied with an exterior ganglion. The two branches of the spinal nerve unite to form a single, short branch, which in turn divides into three subdivisions, **dorsal, ventral** and **visceral.**

Ventral Surface of the Brain

Carefully dissect out the brain by loosening the cranial nerves. Take as much of the cranial nerves with the brain as possible so that they may be used as landmarks. Place the removed brain in a watchglass with alcohol or water for study. A small hand lens of 3 diameters magnification will be of service for this work.

Drawing 24. Make a drawing of the brain X 6, labeling all structures.

Show the origins of the cranial nerves as they come off from the different regions.

The **olfactory** and **cerebral** lobes show no unusual characteristics. The **diencephalon** is not structurally separated from the **mesencephalon.** The optic nerve comes out on the ventral, midline of this part of the brain. The **pituitary body** is a large structure that extends well back towards the medulla. If carefully dissected out, all of this structure will remain attached, as it rests on the floor of the brain case and is not in a depression as in the higher vertebrates. There is no **sella turcica** in Necturus. The **metencephalon** and **mesencephalon** are closely connected with no external marks to separate them. The **medulla** is separated from the **metencephalon** by the enlarged anterior end of the

medulla itself. This swelling is formed by the **crura cerebri** where the large dorsal paths of the medulla must curve to the sides to get around the **fossa rhomboidalis.** The ventral surfaces of both the medulla and the spinal cord are marked by a median groove.

Sagittal Section of the Brain

Place the brain on a piece of cork, wax or other soft material and make a sagittal section with a razor blade or a sharp scalpel. Make this cut by gently pulling the blade along the median line. If the brain is fairly well hardened, this cut is not difficult to make, even in formaldehyde specimens. Place the sections in alcohol or water and study the cut surface.

The first and second ventricles are in the cerebral lobes. They are long cavities, extending well through this section of the brain. The **foramina of Monro** or **interventricular foramina,** are triangular openings that lead from the third ventricle to these paired ventricles of the anterior lobes of the brain. A membranous mass the **telea chorioidea** will be observed extending into the first and second ventricles. This is concerned in the metabolism of the brain. The third ventricle is in the diencephalon or 'twixt brain. The walls are thin on the dorsal side and contain paired cavities; that extend into the optic lobes. These are the **mesocoeles.** The cavity of the optic lobes is not extensive in this animal.

The **iter** is the passage through the mesencephalon. It is rather wide in this form and not the small tube that it is in the higher vertebrates. It continues the passage through the brain to the fourth ventricle.

The **fourth ventricle** is a large cavity in the posterior part of the brain. From the dorsal side it is triangular with a long extension running posteriorly along the medulla. It is covered with non-nervous material and is

supplied with a **chorioid plexus**. The borders of this ventricle form the **fossa rhomboidalis** of the dorsal side of the brain.

The **crura cerebri** are formed by the widening out of this ventricle at the anterior end of the medulla, thus forcing the fibers that were more dorsal on the cord, to bend sharply to one side at this point.

DRAWING 25. Make a drawing of this sagittal section X 6.

The **flexures** are not very evident in the adult brain of Necturus.

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